Landscape Structure and Dynamics of the Mu-Us Sands, China

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Abstract

Natural landscape unit of the Mu-Us Sands are classified into four types as hill, active sand dune, fixed sand dune and meadow. Pastoral use is concentrated on meadow. Sand-dune-fixation planting and windbreak tree-planting are applied on active sand dune and on meadow, respectively. The development of crop field and the results of intensive tree planting were clearly recognized in satellite remote-sensing images. The biomass in the basin of the reservoir was much suppressed in 1993 due to the decline of groundwater level. There is a possiblity that it was caused by the increase of irrigational use.

1. Introduction

Desertification has been one of the most serious environmental problems in China. The Mu-Us Sands is well known as a representative area which has long histories of desertification and efforts of revegetation. To evaluate the effects of desertification and revegetation, effective way of landscape monitoring is required.

This year, this area is noticed as a cause of the discontinuity of the Huan-He River. Newspaper reported that the Huan-He River could not have reached the sea for a long period in these years because of the lack of water-flow. There is an opinion that revegetation and agricultural development of semi-arid region including the Mu-Us Sands affect the over-consumption of water resources of the Huan-He River.

For sustainable use of this region, eco-functional studies with large spatial scales are requested. In this paper, landscape structure and function of the Mu-Us Sands are shown at first. In the later half part, actual dynamics of landscape is analyzed with the comparison of two satellite images in 1978 and 1993.

2. Landscape structure of the Mu-Us Sands

Figure 1 Landscape structure and geological base of the Mu-Us Sands.

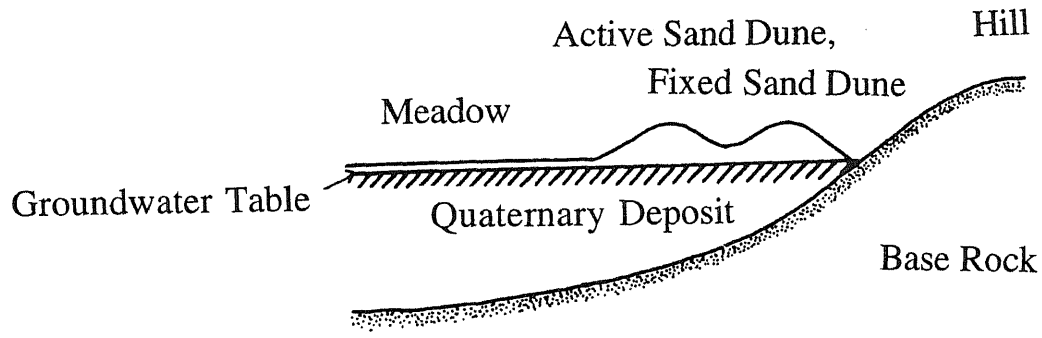

Table 1 Ecological properties of the landscape elements of the Mu-Us Sands.

Landscape element	Area (km^2)	Vegetation	Dominant plants	Soil
Hill	2408	Sparse grasses with half-shrubs	*Stipa* spp. *Lespedeza davurica* *Artemisia frigida*	Thin layer of chestnut soil or brown soil
Active sand dune	14408	Bare ground with few psammophytes	*Agriophyllum arenarium*	Sand
Fixed sand dune	14586	Shrubs and half-shrubs with grasses	*Artemisia ordosica* *Caragana korshinskii* *Sabina vulgaris*	Chestnut soil (topsoil) and sand (subsoil)
Meadow	5447	Perennial grasses	*Carex stenophylla* *Puccinallia tenuifolia* *Calamagrostis pseudophragmites* *Aneurolepidium dasystachys* *Achnatherum splendens*	Meadow soil partly with peat layer, or saline soil

Landscape element	Soil moisture	Land stability	Risk of desertification	Land use
Hill	Dry	Stable	Medium erosibility	Pasture with low productivity
Active sand dune	Medium with quite dry surface layer	Unstable	-	Sand dune fixation planting
Fixed sand dune	Dry	Stable	High erosibility	Conservation
Meadow	Wet	Stable	Low erosibility, high risk of salinization	Pasture, hayfield, crop field, windbreak planting

The Mu-Us Sands develops on the Ordos Plateau which extends flat for 40,000km^2 at the altitude of 1000 to 1500m. It is situated in the ecotone between the temperate arid and humid regions. Though the average of annual precipitation is 362 mm, not so low for steppe, the ecosystem is not stable because of the large year-to-year variance of climate.

The direct origin of sand accumulation is considered to be Quaternary deposits in dry and humid periods which were supplied from weathered sand stone originated in the Mesozoic era. Such sandy deposits cover the wide and flat basin formed on stable geological basis.

Human impact is recognized as the major factor of desertification. Though this area belongs to pastoral region, settlement of farmers has been sometimes promoted in modern history. Inappropriate cultivation had destroyed vegetation and thin soil-layer, which invited the extensive wind-erosion of land surface.

From the ecological point of view, the total landscape of the current Mu-Us Sands mainly consists of the following four landscape elements; hill, meadow, active sand dune and fixed sand dune (Fig.-1). Each landscape element is characterized by its physical attributes as follows;

1) Condition of geomorphologic force. Hill is eroded by the hydrodynamic force. Sand dune is formed under the aeolian force. In particular, mobility of active sand dune is wholly controlled by wind condition.

2) Water supply to soil. Since the groundwater level is high at meadow, soil moisture is not only supplied by precipitation but also by groundwater. At hill and sand dune, as the groundwater level is low, water supply to psammophytes and xerophytes is almost due to precipitation.

3) Soil composition. Active sand dune is constructed by sands with regular particles. Soil of hill, fixed sand dune and meadow contains more or less fine particles as loess deposits and organic products.

The ecological properties of each element are summarized in Table 1. Primary factor of habitat is soil moisture condition. As the soil moisture condition is dry in hill and sand dune, such habitats are occupied by xerophytes and psammophytes. In meadow, soil moisture is so wet that the land is covered by mesic and hydric grasses. A part of meadow with saline soil is dominated by halophytes.

Soil fertility is high in meadow, therefore plant productivity is large. Meadow is the major field of pastoral life and most highly utilized. The productivity of grassland is affected by the changes of groundwater level and its salinity.

Fixed sand dune has two layers of soil with contrary properties. Topsoil is fertile and has high water-holding capacity. However, its layer is thin and the subsoil is so sterile. Since the fertility of topsoil is high, fixed sand dune has been sometimes developed as farmland. But such farmland has been abandoned because its productivity quickly decreased. Abandoned field on fixed sand dune is apt to be eroded by strong wind without covers. Consequently, fixed sand dune easily changes to active sand dune through such desertification processes.

Active sand dune is subjected to aeolian force. Plant establishment is very hard due to high erosibility except some specific psammophytes. Even in active sand dune, if the wind force was

reduced under some conditions, sand dune fixating plants such as *Artemisia ordosica* could invade. Development of pioneer plants promotes the process of sand dune fixation and vegetative succession. Through these processes, active sand dune changes to fixed sand dune.

3. Method of landscape change monitoring with satellite data

Two NDVI images of the south-eastern part of the Mu-Us Sands were produced from the data of LANDSAT/MSS (1978/8/19) and MOS/MESSR (1993/7/17). Geometric relationship of two images was adjusted by the nearest neighbor resampling method. Radiance was transformed from the digital value of each satellite using each inherent equations. NDVI (normalized differential vegetation index) was calculated with the following equation;

$$NDVI = (NIR - R) / (NIR + R),$$

where, NIR and R show radiance in the region of near-infrared wave and red wave. NDVI is considered to represent the abundance of vegetation.

The changes of NDVI image were compared with the land use, which was identified with the map of "Natural Condition and Improvement of the Mu-Us Sandy District" published in 1983.

4. Interpretation of the changes of landscape

Fig.-2 shows NDVI images of the south-eastern part of the Mu-Us Sands in the summer of 1978 and 1993. From the north and west part to the center of each image, the Mu-Us Sands is located on the Ordos Plateau. Here, I call it "plateau area" in a simple word. The south-eastern corner of the figure belongs to the loessial district which presents deep relief, namely the Huan-Tu (Yellow Soil) Hills. I call it "loess area". In the boundary of them, some rivers carve valleys and flow towards the south-eastern direction. The word, "boundary area" is used for it. Yu-Lin City, the place of local government and the economic center of this area, is located along the Yu-Xi-He River.

In this figure, dark tone shows the place with high NDVI. The plateau area consists of various tones of mosaics. Compared with the land use map, dark tone part, dark gray part and light gray part almost correspond to the following landscape units; meadow, fixed sand dune and active sand dune, respectively. The white part shows the surface of water. The boundary area is dominated by light gray parts, that is, active sand dune. Riverside plain shows the dark tone with the striking contrast to active sand dune. It shows crop field and riparian vegetation. The loess area is colored with gray.

Fig.-3 shows the image of the changes of NDVI from 1978 to 1993. The dark tone shows the increase of biomass, while the light tone shows the decrease of it. In this figure, some characteristic site with sharp changes can be pointed out.

NDVI-increased place is observed along the rivers. It illustrates that crop field has expanded in this location. There are other NDVI-increased places as Site A and B in Fig.-3. The landscape type of Site A belongs to meadow and the land use of it is described as crop field in the map. This site also

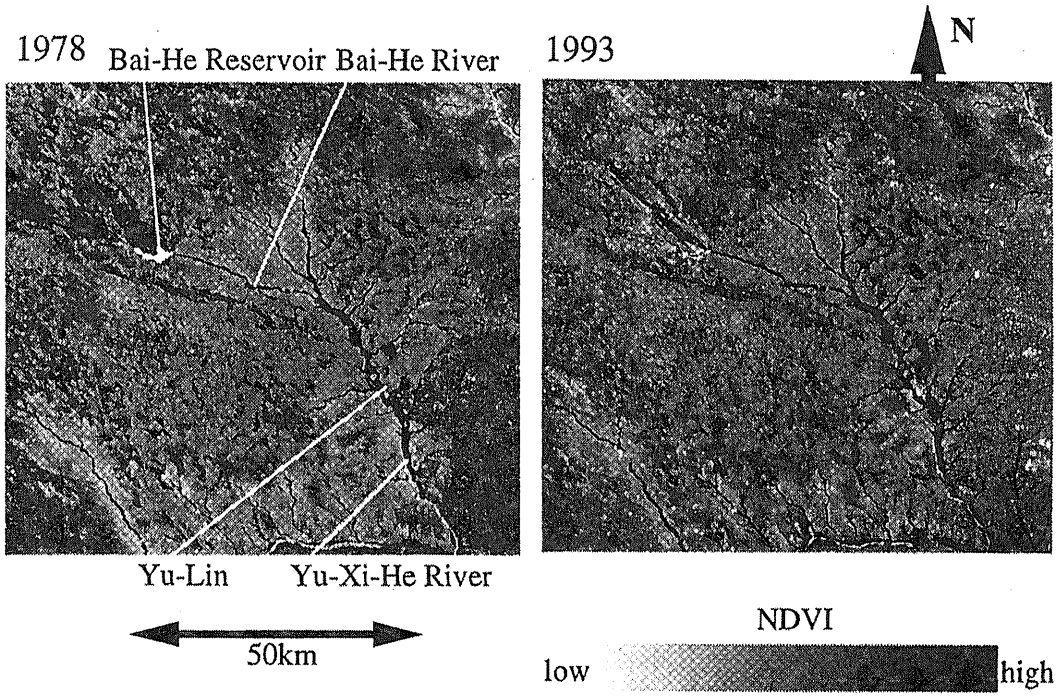

Figure 2 NDVI images of the south-eastern part of the Mu-Us Sands in the summer of 1978 and 1993.

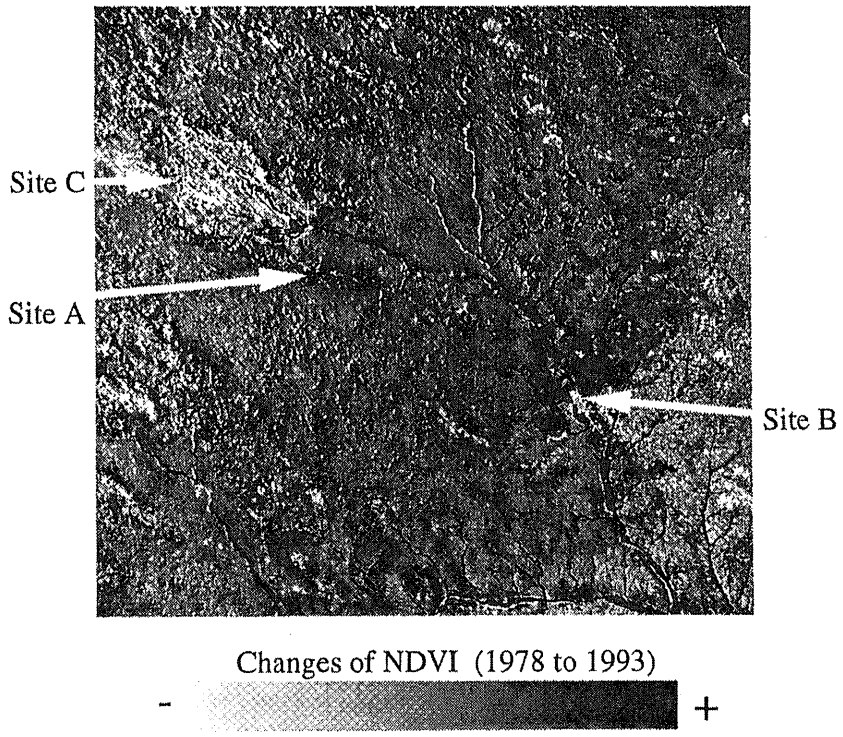

Figure 3 Image of NDVI-changes of the south-eastern part of the Mu-Us Sands from 1978 to 1993.

overlaps with the places where tree-planting project was intensively promoted.

Site B corresponds to Yu-Lin City and its surroundings. As the NDVI of the center of it decreased, it is considered that urbanization has proceeded in the city area. The increase of NDVI in its surroundings shows that farmland and windbreak planting have been developed near the city area.

On the other hand, prominent NDVI-decreased place was recognized in the basin of the Bai-He Reservoir (Site C). The most part of degenerated vegetation around the Bai-He Reservoir is subjected to natural meadow. Since plants is naturally irrigated by groundwater in meadow, primary factor of this phenomenon should be attributed to the decline of groundwater level. The meteorological data of Tai-Yuan, 280km apart eastward from Yu-Lin, shows that the precipitation from June to July in 1978 was 163mm , while in 1993, that was 62mm. That of Lan-Zhou, 550km apart westward from Yu-Lin, was 194mm in 1978 and 99mm in 1993. Consequently, it is easily speculated that the precipitation in the early summer of 1993 was much less than 1978 here. It is considered that the groundwater level is apt to change because the catchment of groundwater is enclosed in the Ordos Plateau without the effective recharged area. The changes of precipitation are supposed to affect the groundwater level here.

However, the decline of it is partly due to an anthropogenic factor, because the decrease of NDVI was eminent, compared with other meadows. As mentioned above, agricultural development and tree planting have been promoted down-stream along the Bai-He River. Such development should increase the consumption of water resource of the Bai-He Reservoir; as a result, the groundwater table of the basin might particularly fall down.

5. Conclusion

The increase of NDVI was most obvious at the places where human activity dominates. It should be appreciated that human efforts have operated well as a promoting force of revegetation in this region. Nevertheless, there is a possibility that such development also promoted the decline of water resources as shown in the Bai-He Reservoir. Agricultural development and man-made revegetation often have both sides of effect in semi-arid area. To secure sustainable development, further quantitative researches are required in the style of inter-disciplinary study among ecology, hydrology, meteorology and related fields.

6. References

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